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EFFECTS OF INFORMATION PROCESSING REQUIREMENTS ON REACTION TIME--ETC(U)

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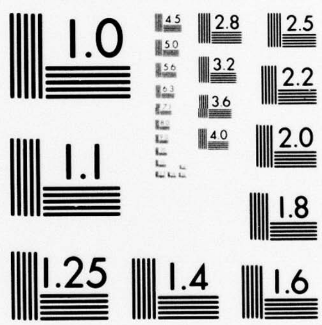

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EFFECTS OF INFORMATION PROCESSING REQUIREMENTS ON REACTION TIME OF THE EYE

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ABSTRACT

This experiment measured eye reaction time as a function of presence or absence of a central control task, type of command, and knowledge of target direction prior to command. It was found that eye reaction time was greater when a subject was involved in a central tracking task than when he was not; it was greater when the command was symbolic than when it was spatial; and it was longer when the target direction was unknown prior to command. These variables also interacted, so that the effect of unknown target direction was greater with a symbolic command.

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INTRODUCTION

Classic research on the reaction time of the eye has shown that it usually takes about 180-230 msec from the time of a command to refixate until the eye begins to move toward the target (Diefendorf and Dodge, 1908; Westheimer, 1954; Bartz, 1962). These studies, however, have generally used a simple paradigm or a small number of highly practiced subjects. It is possible that the reaction times obtained are limited to the experimental contexts and may not be found in more complex situations.

Carlow, Dell'Osso, Troost, Daroff and Birkett (1975) presented ten naive subjects with a disjunctive task (response to either a step or pulse-step target motion to either the right or left). Eye reaction times varied widely between subjects, with an overall mean of about 255 msec. They attributed their higher eye latency values to use of a paradigm which did not allow for predictive responses. Increased uncertainty led to increased reaction times. Bertera, Callan, Parsons and Pishkin (1975) obtained simple eye reaction times of about 250 msec in response to an auditory stimulus. With a choice reaction time task, eye reaction times increased to about 390 msec. They also found a left-right signal-response compatibility effect for eye reaction times, with a response to the side opposite the incoming auditory signnal taking longer than a response to the same side. The magnitude of the compatibility effect was comparable to that obtained with manual responses to the same stimuli.

Several experiments at the University of Wisconsin have used a paradigm in which the command to refixate is given while subjects are engaged in a central tracking task. Robinson and Subelman (1975) obtained an overall mean eye reaction time of 634 msec, accompanied by an increase in inter-subject variability when compared with the results of more traditional refixation experiments without a central control task. They also observed that subjects sometimes used what they called an initial compensatory pattern of eye-head movements. In the compensatory pattern, the head begins to move toward the target while the eye remains fixated on the central task, thus moving negatively with respect to the head, for a brief period before initiating a saccade toward the target. This pattern is in contrast to the classic mode in which the eye begins to move toward the target first, followed about 50 msec later by the head. (See London, Bice and Robinson, 1978, for a comprehensive review of the compensatory pattern of eye-head movements.)

Robinson and Bond (1975) also used the interruption of a tracking task to look at eye reaction time. They reported an overall eye reaction time of 502 msec. They also found that eye reaction time (t_e) increased with target angle. The entire effect of target angle, however, was accounted for by the longer t_e in the compensatory pattern. When looking at t_e for movements in the classical pattern only, eye reaction time was on the order of 430 msec. Thus the substantial increase in t_e when subjects are engaged in a central control task can be attrib-

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uted in part to use of the compensatory mode. But even when considering only classic eye-head movements, there is a considerable increase in reaction time over the oft quoted 200 msec.

It seems likely that reaction time of the eye does not differ qualitatively from other motor response times and should be affected in a similar manner by a variety of factors. This experiment was designed to measure the effects of information processing variables on eye reaction time (t_e), specifically: 1) presence of a competing central tracking task, 2) geometric vs symbolic command signal, and 3) prior knowledge of target direction (left-right).

METHOD

Subjects

The subjects were eight male University of Wisconsin students with 20-20 uncorrected vision. Each was paid for his participation.

Apparatus

The subject was seated in front of a monitor at eye-level 90 cm away. The pursuit control task was displayed on the monitor via closed circuit TV. Three RCA numitron digital tubes were attached to the lower part of the TV screen. The center tube was used to display the instruction and symbolic command signals for the side-target task. The tubes to the right and to the left of center were used for the geometric command signals. At eye level 90 degrees to the right and left of center, also at a distance of 90 cm from the subject, were additional numitron tubes which served as the side targets.

The tracking task display consisted of a dot moving randomly (0 - .10 Hz bandwidth) in a vertical direction as a command input and a vertically moving circle as system output. The subject's input was made through a joystick which could be moved forward or back. The relation between the subject's input and system output was second order, with an acceleration gain of .192cm/sec^2/degree.

A button was centered on the joystick to measure the subject's reaction time for the side-target task. When the subject pushed the button, his reaction time was recorded and the target display was extinguished.

Horizontal eye movements of the subject were measured with a Biometrics SGHV-2 eye monitor which utilizes photocells to detect changes in reflected infrared light. Head movements were measured by a potentiometer attached to a bicycle helmet which was suspended by a counterbalanced articulated arm.

Design

There were four independent variables in this experiment, each with two levels:

1. Tracking/no tracking ($T,\overline{T}$): On one half of the trials subjects were engaged in a central tracking task; on one half of the trials they had no central task to perform.

2. Command type: On one half of the trials the command for the side-target task was geometric (G) (a bar appearing either to the right or to the left of center to indicate direction of the side target). On the other half of the trials, the command was symbolic (S) (either a "5" or a "6" on the center tube to indicate direction).

3. Known/unknown ($K,\overline{K}$): On one half of the trials the subject was instructed as to the target direction prior to time of command; on the other half he had no directional instructions until the command was given.

4. Left/right: On one half of the trials the target was to the left, and on the other half it was to the right.

The first two independent variables were blocked, with subjects receiving blocks of trials with symbolic and with spatial commands within tracking and no-tracking blocks. Order of presentation of the blocked variables was counterbalanced between subjects. The known/unknown and left/right variables were randomized within each of the four trial blocks. Each trial block consisted of 24 trials, six of each combination of the known/unknown and left/right variables, and each subject received four blocks of trials, for a total of 96 experimental trials.

The dependent variables in this experiment were:

1. t_e: time from command until the eye begins to move in the direction of the target;

2. t_h: time from command until the head begins to move in the direction of the target;

3. percent compensatory eye-head movements.

Procedure

Subjects were seated and the eye and head monitors were adjusted. The chair was positioned so that displays were at the subject's eye level at a distance of 90 cm. Subjects were then given instructions for the first block of trials, followed by ten practice trials. Prior to the tracking block of trials, subjects were allowed five minutes to practice the tracking task.

The side-target trial structure was as follows: The center numitron tube went on, displaying either a "5" (upcoming trial to the left), a "6" (next trial to the right), or a "0" (trial side unknown). This instruction remained on for five seconds, then went off. After a random interval (1-3 seconds), the command signal was presented. For symbolic trial blocks, the command signal was either a "5" (left) or a "6" (right). For geometric trial blocks, the command signal was a vertical bar appearing either to the left (left target) or to the right (right target) of center. As soon as the command signal occurred, the subject was to look as quickly as possible to the target at 90 degrees to the side indicated by the command. As soon as he recognized the digit displayed on the target, he pushed the reaction-time button on the joystick, which extinguished the display, then returned to center to await the next trial. The target digit was reported to the experimenter via an intercom. Target reaction time and correctness of identification were measured to assure subject compliance with the instructed task. They were not dependent variables of interest to this study. During trial blocks when the subject was performing a tracking task in addition to the side-target task, the subject was instructed to perform the side-target task as quickly as possible while keeping the moving dot inside the circle.

After each set of experimental trials, the subject was given a short break, followed by instructions, practice trials and the next block of experimental trials. After completion of the final block, the subject was debriefed and paid.

RESULTS AND DISCUSSION

Eye Reaction Time

Eye reaction times (t_e) by experimental condition are shown in Figure 1. Since a t-test showed no significant differences between left and right trials, results reported are collapsed over the left/right variable. Over all conditions, the mean time from command until the eye began to move in the direction of the target was 479 msec, ranging from 362 msec in the no-tracking-geometric-known condition to 628 msec in the tracking-symbolic-unknown condition. An analysis of variance showed significant main effects for all three independent variables. As shown in Table 1, t_e was greater while

Table 1. Eye Reaction Time, msec.

Tracking		Command		Direction	
T	$\bar{T}$	G	S	K	$\bar{K}$
535	422	428	530	446	512

the subject was engaged in a tracking task than when he was not ($F(1,49) = 73.27$, $p < .05$); t_e was greater with a symbolic command than with a spatial command ($F(1,49) = 58.18$, $p < .05$); and t_e was greater when the target direction was unknown prior to time of command ($F(1,49) = 24.34$, $p < .05$). In addition, there was a significant interaction between the known/unknown and command variables ($F(1,49) = 5.87$, $p < .05$), with the effect of unknown target direction greater with a symbolic command than with a geometric command (see Figure 2).

Head Reaction Time

Head reaction times (t_h), as shown in Figure 1, followed the same patterns as eye reaction times, but averaged 518 msec, about 39 msec longer than t_e.

Eye reaction times obtained are considerably longer than those traditionally reported in the literature, while the differences between t_e and t_h are somewhat less than the normally found 50 msec. This can be attributed in part to the use of compensatory eye-head movements. In the compensatory mode, the head begins to move toward the target before the eye, as shown in Figure 3, so that t_h is actually smaller than t_e.

Compensation

Subjects used a compensatory pattern of eye-head movements in 19% of all trials. Percent compensatory trials by experimental condition are shown in Figure 4. An analysis of variance showed subjects used significantly more compensatory movements in the tracking trials (28%) than in the no-tracking trials (10%). Subjects also used more compensation with a symbolic command (23%)

than with a geometric command (15%). Differences in amount of compensation between the known and unknown conditions were not significant, nor were overall differences between left and right.

The analysis of variance showed a significant interaction between the tracking and command type variables. Subjects used a significantly higher percent compensation for a symbolic command only in the no-tracking condition. In the absence of a tracking task, the symbolic command may present enough information to be processed to induce compensation while the geometric command does not. When subjects are tracking, the greater amount of compensation used masks any of the smaller differences between command types. Prior to this experiment, initial compensation had been observed only when subjects were engaged in a central control task. It now appears that compensation is more likely to occur when there is some central information to be processed at the time of a refixation command. As the complexity of this central information increases, so does not only the percent compensatory movements but also the number of subjects using compensation (see Figure 4).

Analysis of percent compensation showed significant differences between subjects, as well as interactions between subjects and other independent variables, most notably the left/right variable. Six out of the eight subjects in the experiment used compensatory movements, ranging from 2% to 47% over all conditions for these six subjects. Of the subjects using compensation, two subjects compensated exclusively to the right, one subject compensated primarily to the right, two compensated mostly to the left, and one about the same amount to the left and to the right. The reasons for these biases to compensate more to one side are unclear at this writing, but they do not appear to be related to handedness.

Classical (non-compensatory) trials had a mean eye reaction time (t_e) 24 msec shorter than t_e over all trials. The difference between t_h and t_e was 68 msec in the classical trials compared to 39 msec over all trials.

CONCLUSIONS

Reaction time for eye movement and the qualitative relationship between eye and head movement both vary systematically with common information processing variables. The effect of the control tracking task may be of particular practical importance in that in many systems in which rapid visual scans are important the operator is, in fact, interrupting a continuous control task for peripheral data acquisition.

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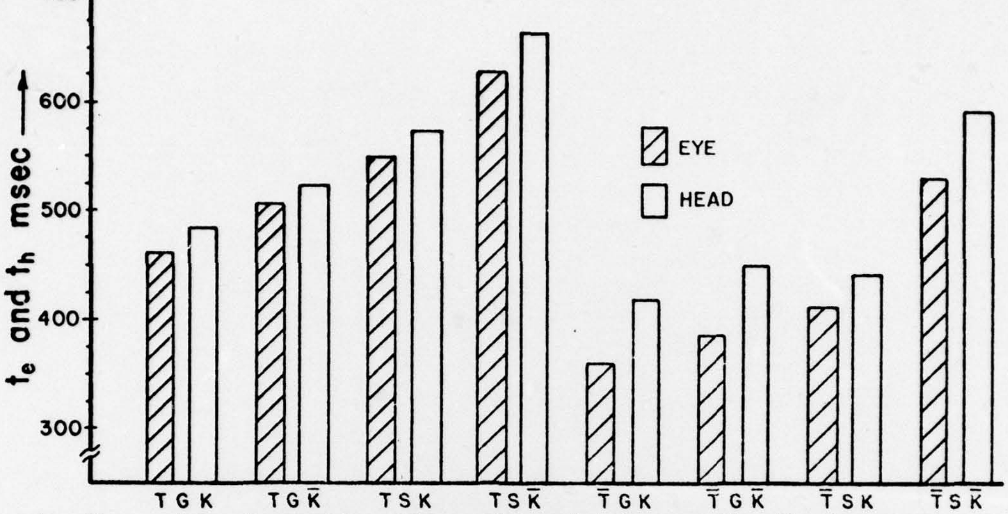

Figure 1. Eye and head reaction times (t_e and t_h) over the three experimental conditions: Tracking (T) or no tracking ($\bar{T}$), geometric (G) or symbolic (S) command, and known (K) or unknown ($\bar{K}$) direction.

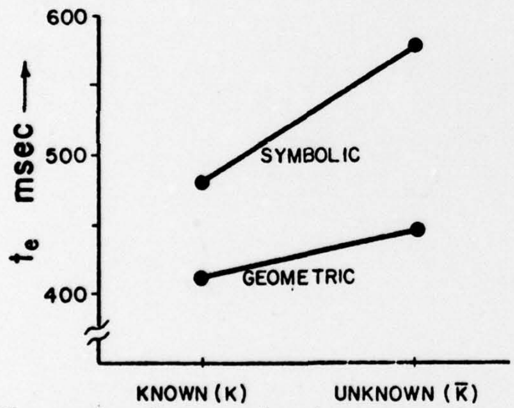

Figure 2. Interaction between prior knowledge of direction and command type.

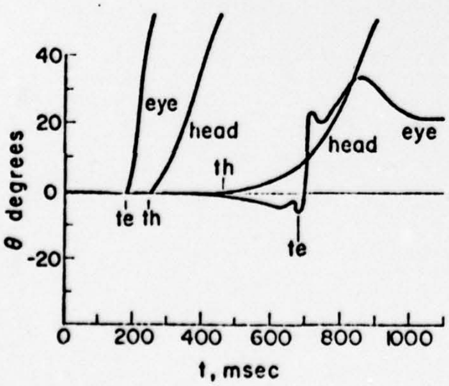

Figure 3. Classical and compensatory modes of initial eye and head movement.

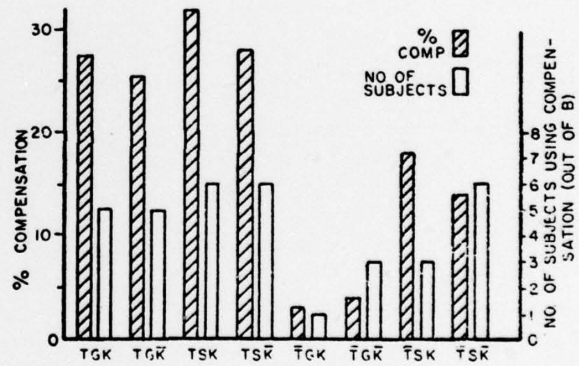

Figure 4. Percent compensatory trials and number of subjects using compensation over the same three experimental conditions defined in Figure 1.